Hilbert-Huang Transform Data Processing System (HHT-DPS)

NASA Goddard Space Flight Center
Hilbert-Huang Transform Advanced Technology Briefing

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Project Goal

- Design and build a turn-key, user-friendly, file driven, PC based data processing system that implements the "HHT" algorithms and processing methods developed by Dr. Norden Huang
- Phase 1 development – "Software Only" version
- Phase 2 development – "Hardware Accelerated" version

Project Objectives

- Use Dr. Huang’s published papers and NASA patented algorithms as the starting point (see Reference [1], [2], [3] on chart 21)
- Port, analyze and re-use only the available and proven HHT source code fragments and Matlab scripts
- Use existing Empirical Mode Decomposition executable (EMD0.exe) as a functional benchmark

Project Objectives (continued)

- Simple PC based Microsoft Windows environment
- Straightforward operation via graphical user interface
- User configurable processing options
- Read user data input file, generate user data output files
- “Quick Look” data display capability only, assumes users have individually preferred data analysis tools in their lab (MathWorks - Matlab, Visual Numerics - PV Wave, Research Systems - IDL, etc.)

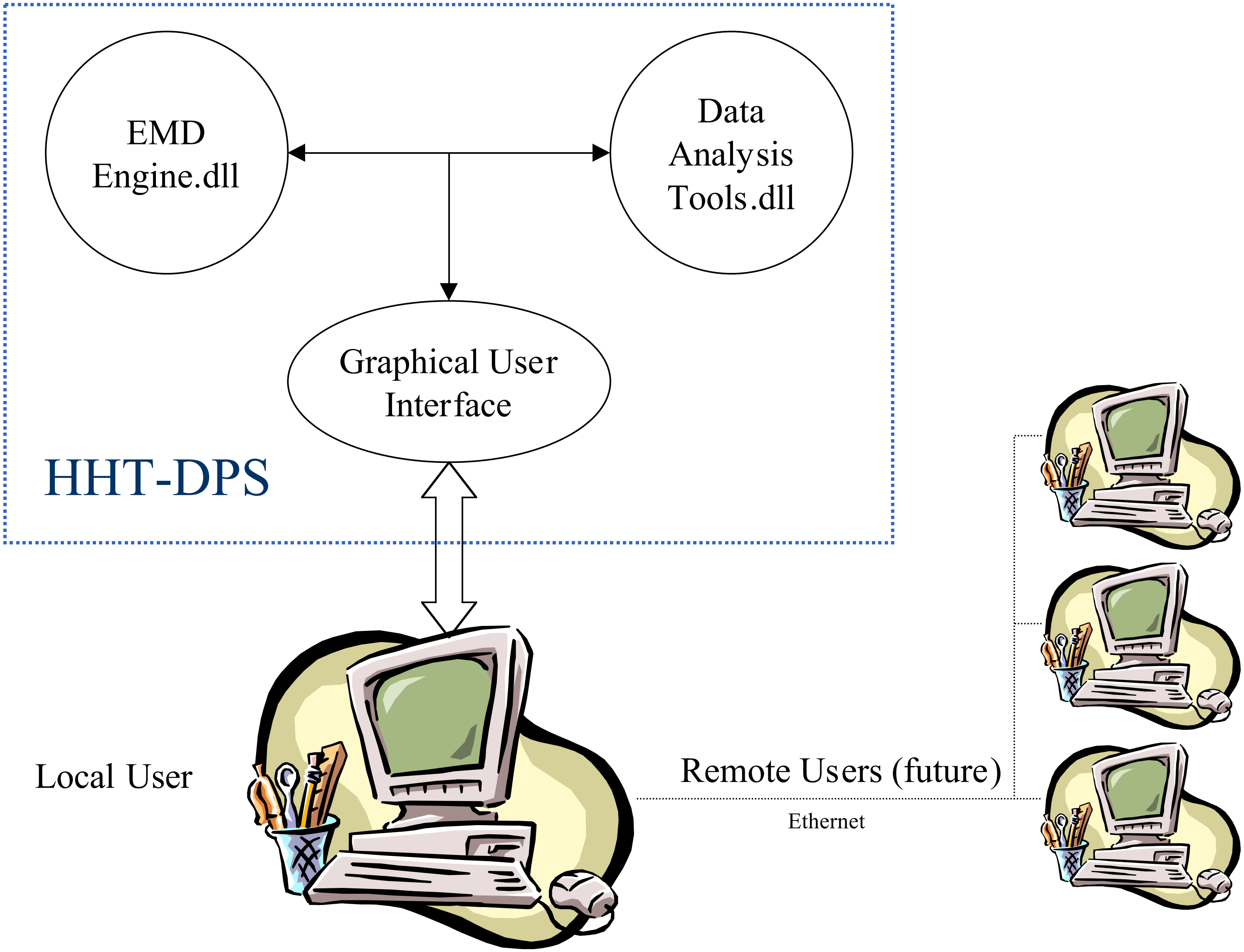
Project Development Approach

- Prototype new Empirical Mode Decomposition (EMD) routines *in an algorithmic language (Matlab)* and reproduce results comparable with the existing EMD0.exe executable program for the same data source
- Where results differ, analyze performance in collaboration with Dr. Huang, iterate until data is correct (note: where there are differences in results the new HHT-DPS product now takes precedence, based on the up-to-date contributions by Dr. Huang)
- Implement all prototyped algorithms (EMD and Basic Spectrum Analysis Matlab scripts) in ANSII standard 'C' (keeping hardware acceleration in mind)

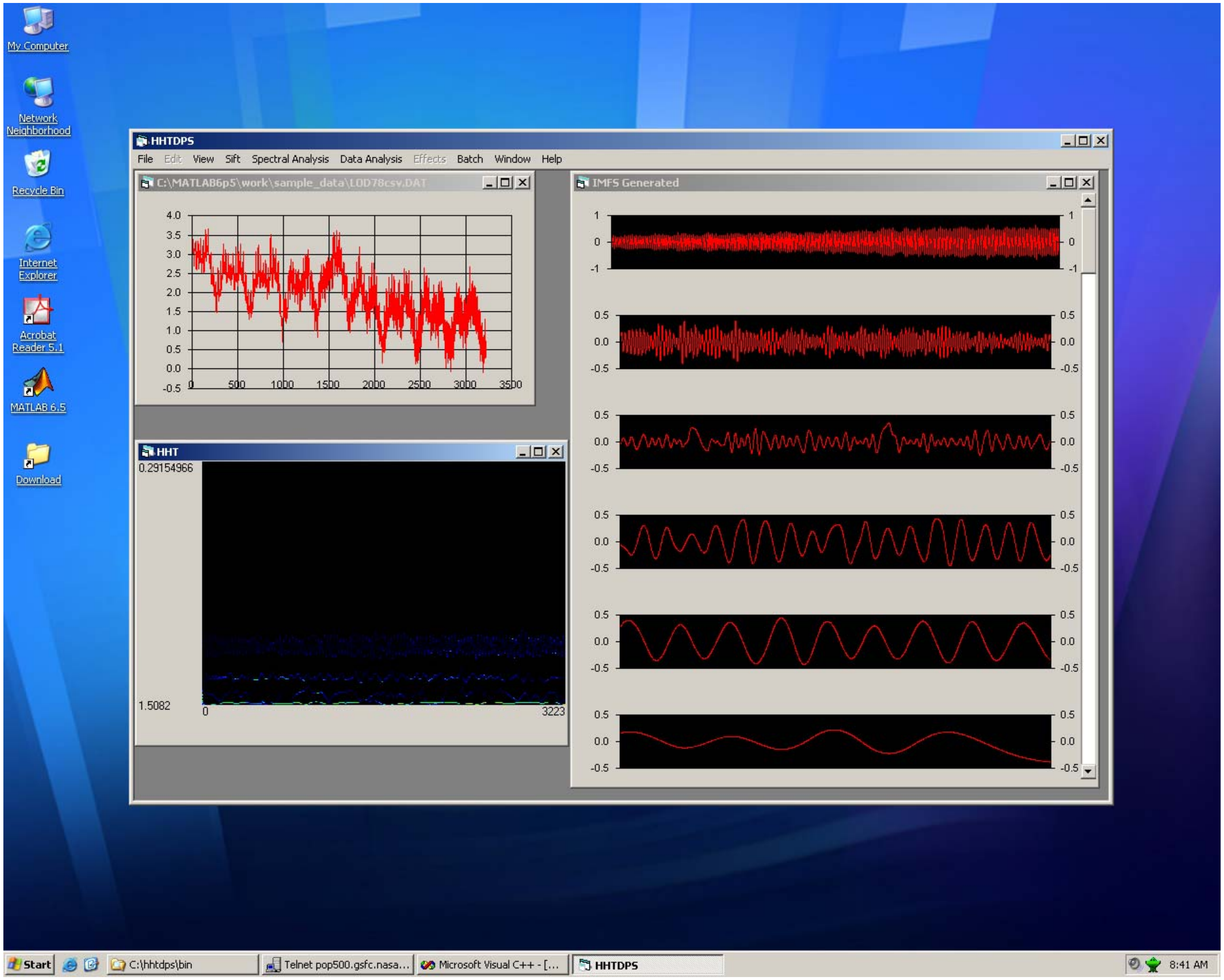
Project Development Approach (continued)

- Develop user interface and system control modules
- Integrate and test system modules with benchmark data set (length of day)
- Determine system capabilities and limitations by testing HHT-DPS against different data sources at different data rates, volumes and magnitudes
- Document the system (official “Release V1.0” software package, code documentation, user’s guide, change request forms, problem reports, configuration management)
- All access to HHT-DPS via the GSFC Technology Transfer Program (TTP) office

HHT-DPS Top Level Diagram



HHT-DPS Application



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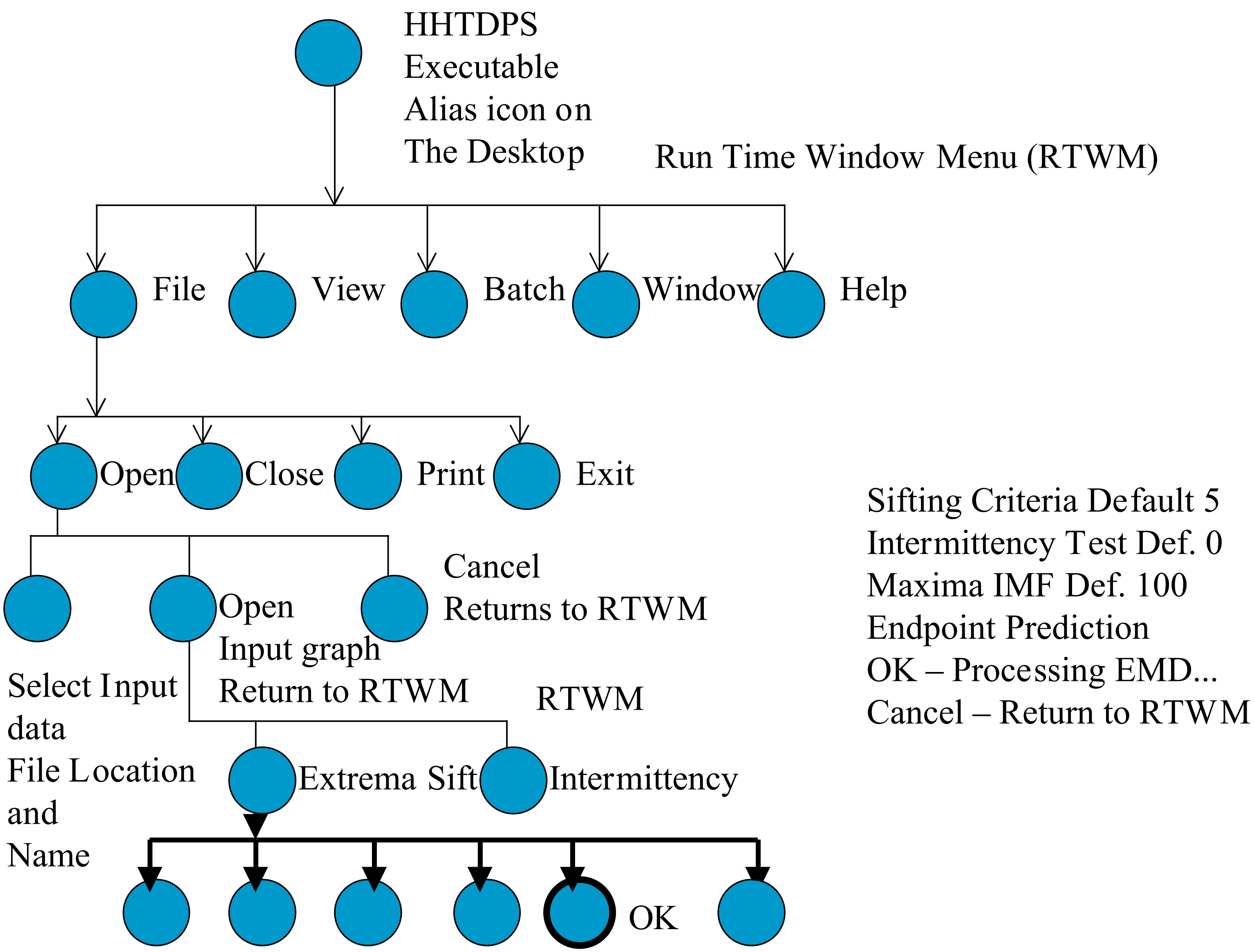
Run Tree



HHTDPS
Executable
Alias icon on
The Desktop

Run Time Window Menu (RTWM)

File View Batch Window Help

Open Close Print Exit

Cancel
Returns to RTWM

Open
Input graph
Return to RTWM

Select Input
data
File Location
and
Name

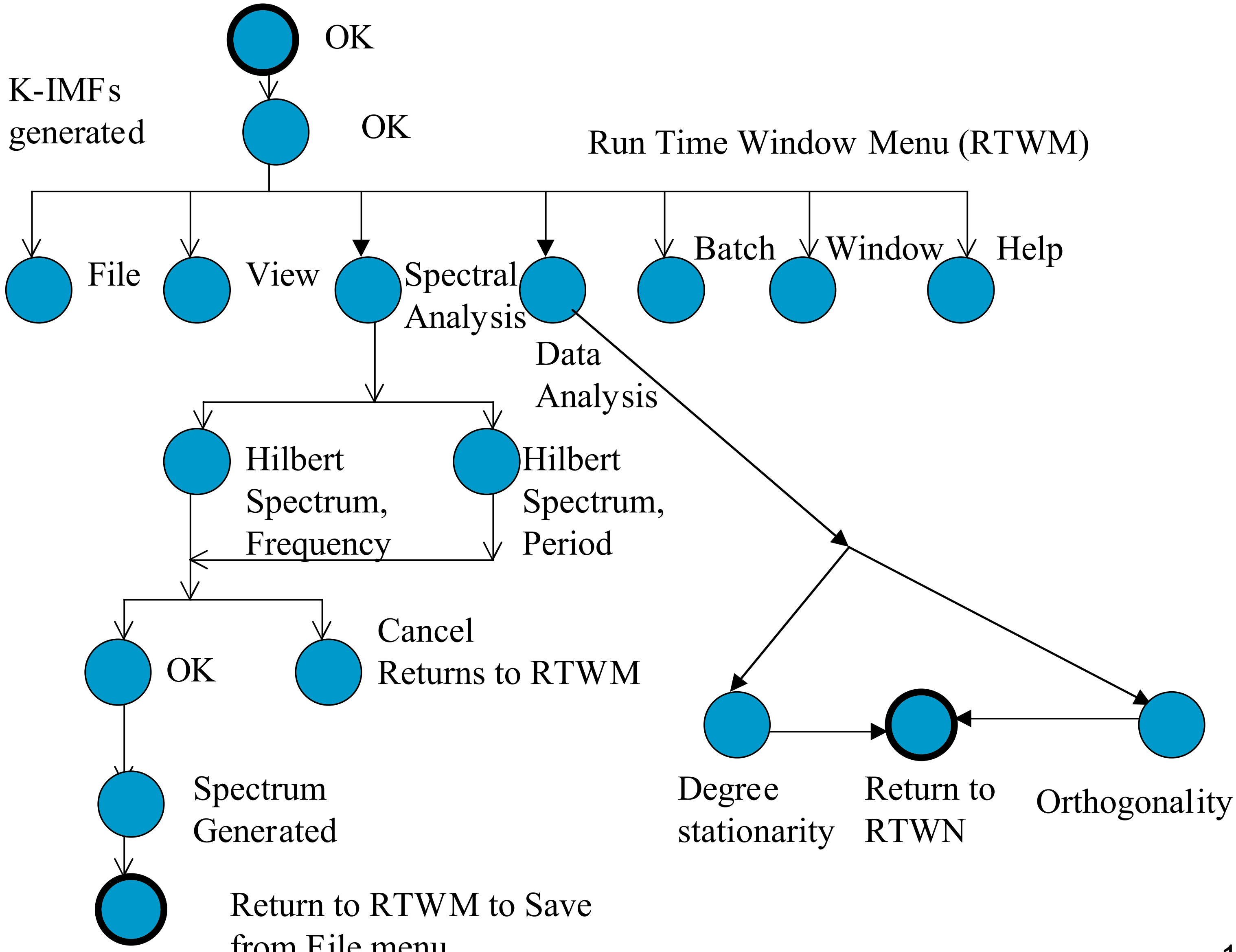
RTWM

Extrema Sift Intermittency

OK

Sifting Criteria Default 5
Intermittency Test Def. 0
Maxima IMF Def. 100
Endpoint Prediction
OK – Processing EMD...
Cancel – Return to RTWM

Run Tree (continued)



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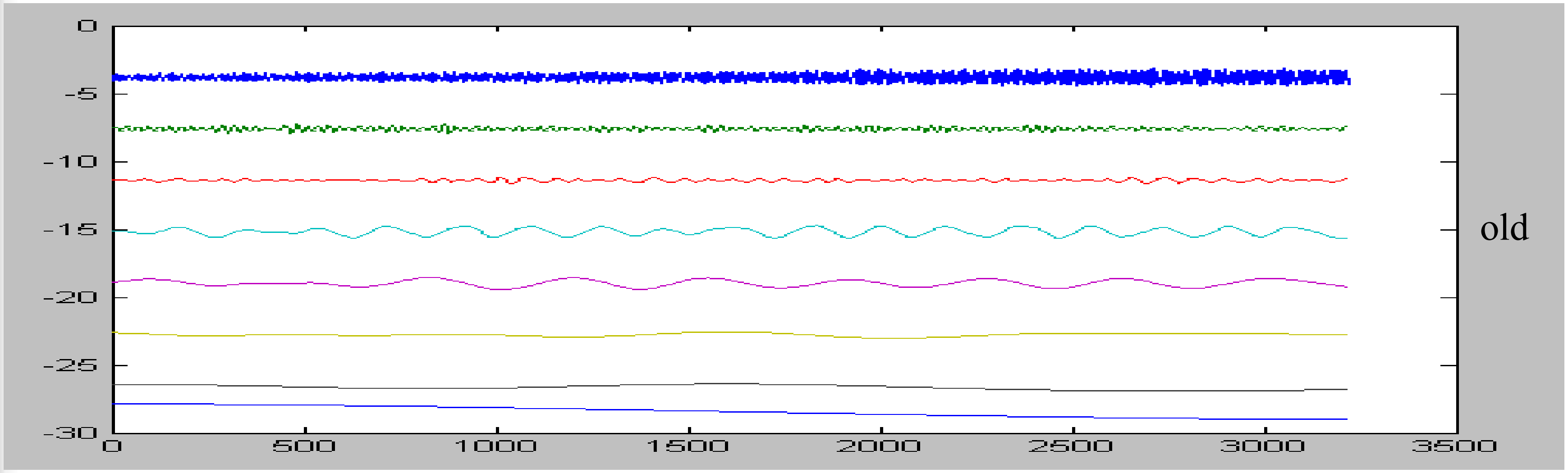
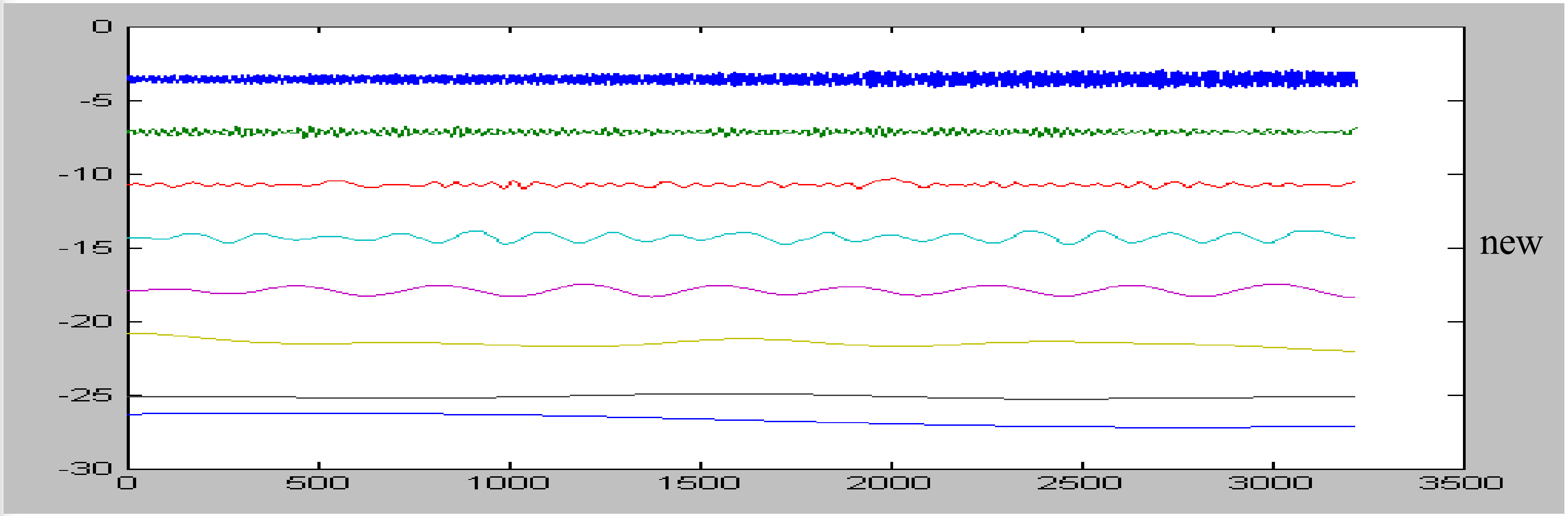
Heritage vs. New HHT-DPS EMD IMFs Comparison for Lod78.dat file





Improvements, Enhancements and Modifications

What was added:

- All EMD computations are in double precision floating point which is consistent with Matlab system
- Extrema points strict selection criteria was applied systematically
- In case of level data segments a special extrema selection method was chosen to handle man-made and theoretical signals
- Input data file batch processing option was added allowing to process multiple input data files concurrently
- End Points Prediction new option Pattern

Improvements, Enhancements and Modifications (continued)

- All existing spectrum analysis Matlab scripts run-time abort problems were resolved before conversion to ‘C’
- 22 Matlab scripts, including 50 Matlab functions – the basic spectrum analysis scripts were re-implemented in ‘C’
- An IFS program to pre-process IMFs for “same magnitude ends and slopes” in order to achieve an improved Hilbert Transform
- GUI - Both EMD and IFS subsystems are integrated in the GUI
- A control switch was added to enable system use for demo distribution

Improvements, Enhancements and Modifications (continued-2)

What was deleted:

- Only the concept of end point linear prediction was used from available source C++ code fragments
- No use was made of any prior source code for EMD development

What was changed:

- Matlab scripts run-time problems corrected

Current HHT-DPS Status

What works:

- All state of the art HHT system functionality has been achieved and tested for available test data inputs: Lod78.dat, sinusoid12.dat, Tune1.dat, tune&noise.dat

Current limitations:

- 1 minute or more of 20 KHz sampled sound data takes longer than expected time to process
- Larger data sets (more than 25000 points) have not been tested

Note: These are the limitations of HHT-DPS and not the HHT method

Current HHT-DPS Status (continued)

Planned near term enhancements:

- Verify processing of large input data files
- Input data formatter
- Combine select outputs

Planned near term tests:

- More tests with data from varying sources (wind, bio-medical, etc.)

HHT-DPS Phase 1 Delivery Configuration

- HHT-DPS Phase 1 (Version 1.0) configuration was frozen on March 13, 2003

- Paper on HHT-DPS Phase 1 development framework is completed and will be submitted to IEEE for publication in April 2003

<u>HHT-DPS Computer Development System Platform</u>

- Microsoft Windows 2000 5.00.21a5, Service Pack 2

- Intel® Xeon™ CPU 1.70 GHz, 528,280 KB RAM

* HHT-DPS demo version CD-ROM will be available through the GSFC Technology Transfer Program (TTP) in April 2003 (will run on standard PC, Xeon µP not required)

Processing Performance Examples

Data complexity vs. processing time using all default processing options:

File Name	Size	Processing Time
Lod78.dat	2688 pts	~ 8 seconds
sinusoid12.dat	1001 pts	~ 5 seconds
Tune1.dat (spike)	2551 pts	~ 13 seconds
tune&noise.dat	2000 pts	~ 5 seconds

HHT-DPS Phase 2 Plan

Hardware acceleration

- Evaluate all HHT-DPS processing modules for computational complexity and benchmark execution time (find bottlenecks)
- Implement bottleneck routines in DSP and/or FPGA hardware (COTS PC plug-in cards) to achieve ~10-50x speed-up
- Status of funding for Phase 2 is still uncertain

Other Future Activities?

- Develop “remote user” interface for access via Internet
- Enhance spectrum analysis tools
- Develop a 2-D data version
- Implement the HHT-DPS in a “flight-like” box for real-time processing on balloon / aircraft flights
- Develop HHT-DPS ASIC component

HHTDPS Sources and References

[1]. “The empirical mode decomposition and the Hilbert spectrum for nonlinear and non-stationary time series analyses” by Norden E. Huang et al, Proc.R Soc. Lond. A (1998) 454, 903-995
[2]. “A new view of nonlinear water waves: The Hilbert Spectrum” by Norden E. Huang at al Annu. Rev. Fluid Mech. 1999, 31 417-457
[3]. Norden E. Huang Patent#6,311,130 B1, Patent Date: Oct. 30, 2001
Patent Name: Computer Implemented Empirical Mode Decomposition Method, Apparatus, and Article of Manufacture for Two-Dimensional Signals
and other existing or pending patents.

Metaphors

We shall not cease from exploration
And at the end of all our exploring
Will be to arrive where we started
And know the place for the first time.

T. S. Eliot

Men occasionally stumble over the truth, but most of them pick themselves up and hurry off as if nothing happened.

Winston Churchill

Appendix. Two Optional Slides on Data Flow

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HHT-DPS User Flow

- Insert user data disk (ascii text “white space delimited” format, 1-D array)

- Select Processing Mode

  - Real Time or Batch

- Select input file name(s)

EMD1 Options (Defaults are used if no selection):

- EMD Completion Criteria

- Intrinsic Mode Function (IMF) Completion Criteria

- Intermittency Vector Threshold

- End Point Prediction Method

HHT-DPS User Flow (continued)

- EMD1 Returns IMFs as Data and Graphs
  - Save IMF data to file, view “quick-look” images
- Select Instantaneous Frequency Spectrum (IFS) Options:
  - Nominal Hilbert Spectrum
  - Marginal Hilbert Spectrum
- IFS1 Returns Spectrum Data and Graphs
  - Save spectrum data and images to disk file
- Select Data Analysis Options:
  - Check IMF Basis Orthogonality
  - Check Signal Stationarity